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Launching the Future... Constellation Program at KSC

Erik C. Denson
Electrical Design Branch
National Aeronautics and Space Administration
Kennedy Space Center, FL, USA
Erik.C.Denson@nasa.gov

Abstract - *With the Constellation Program, NASA is entering a new age of space exploration that will take us back to the Moon, to Mars, and beyond, and NASA is developing the new technology and vehicles to take us there. At the forefront are the Orion spacecraft and the Ares I launch vehicle. As NASA's gateway to space, Kennedy Space Center (KSC) will process and launch the new vehicles. This will require new systems and extensive changes to existing infrastructure. KSC is designing a new mobile launcher, a new launch control system, and new ground support equipment; modifying the Vehicle Assembly Building, one of the launch pads, and other facilities; and launching the Ares I-X flight test. It is an exciting and challenging time to be an engineer at KSC.*

1 Exploration

Why explore? From the time of our birth, humans have felt a primordial urge to explore—to blaze new trails, map new lands, and answer profound questions about ourselves and our universe. It's in our DNA to explore and learn. It's not the destination, but the journey. We will learn a lot along the way. Technology and innovation—gadgets—will lead the way. Biomedical research will tell us how to survive the conditions of an alien environment, including radiation exposure and long-term exposure to space and weightlessness. We have to learn how to live off the land, or, in technical terms, practice *in situ* resource utilization. These innovations and research will spin off new jobs, new markets, and new technology that will improve and save lives and benefit all mankind. At Kennedy Space Center (KSC), the journey is under way. KSC is developing new technologies and systems that will take us on this grand adventure. Who knows what discoveries are ahead of us? Perhaps life on other worlds. KSC is the launch pad to discovery.

2 Constellation Program

The Constellation Program's mission is the "Moon, Mars and Beyond."

By inhabiting the Moon for extended periods, astronauts will search for resources and learn how to work safely in a harsh environment—stepping stones to future exploration. The Moon also offers many clues about the

time when the planets were formed. There are also plans to build a permanent lunar outpost.

On Mars, robotic missions have found evidence of a watery past, suggesting that simple life forms may have developed long ago and may persist beneath the surface today. Human exploration of Mars could provide answers to some profound questions.

As humans and robots work together exploring the Moon and Mars, NASA spacecraft will continue to send back scientific data from across the solar system, laying the groundwork for potential human journeys in deep space.

In parallel with development of new spacecraft for human exploration under the Constellation Program, robotic explorers will serve as trailblazers to reduce the risks and costs of future human operations at the Moon. Robots will build valuable mission experience that can provide insight into the preparations required for extended human presence on Mars and other destinations in the solar system. The first in this wave of robotic probes is the Lunar Reconnaissance Orbiter. Its mission is to create high-resolution maps that will help us to determine the location of the lunar outpost. The Phoenix Lander will explore regions near Mars' polar caps, extract samples of soil and ice, and examine them for evidence of life. The Mars Science Laboratory will collect Martian soil and rock samples and analyze them for organic compounds and environmental conditions that could have supported microbial life in the past or might be capable of supporting it now.

The Constellation Program is developing new systems and vehicles to support the next generation of space exploration. These vehicles will support the International Space Station after the Space Shuttle is retired, as well as missions to the Moon, to Mars, and beyond. Unlike earlier programs, Constellation will directly inherit the legacies of its predecessors, Apollo and Space Shuttle, using parts and concepts of these earlier programs to build more dependable and economical craft. The Orion crew exploration vehicle will take astronauts to the International Space Station and beyond. It will be able to rendezvous with the Altair lunar lander and Ares V

Earth departure stage in low Earth orbit to carry crews to the Moon and, one day, to Mars-bound vehicles assembled in low Earth orbit. Orion will be the Earth entry vehicle for Moon and Mars return flights. Orion's design will borrow its shape from the capsules of the past, but it takes advantage of 21st-century technology in computers, electronics, life support, propulsion, and heat protection systems. Orion is scheduled to fly its first missions to the International Space Station by 2015 and carry out its first sortie to the Moon by 2020. The Ares launch vehicles, named for the Greek god associated with Mars, will carry into orbit astronauts, cargo, and the components needed to go to the Moon and later to Mars. Ares I will be an in-line, two-stage rocket topped by the Orion crew vehicle and its launch abort system. The Ares V cargo launch vehicle will be the heavy lifter of America's next-generation space fleet. The two-stage, vertically stacked launch system will have a 206-ton capacity to low Earth orbit and a 78-ton capacity to lunar orbit. The Altair lunar lander will be capable of landing four astronauts on the Moon, providing life support and a base for week-long initial surface exploration missions, and returning the crew to the Orion spacecraft that will bring them home to Earth. Altair will be launched aboard an Ares V rocket into low Earth orbit, where it will rendezvous with the Orion crew vehicle. All components will be processed at KSC.

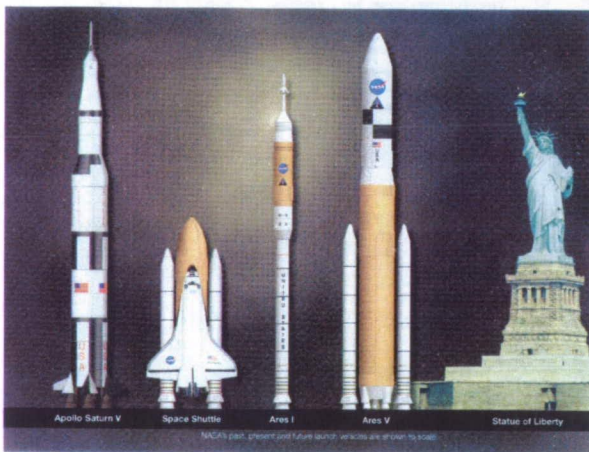


Figure 1. Tuskegee Airmen Congressional Gold Medal

3 Vehicle processing and launch

Components of the new Ares I launch vehicle and the Orion spacecraft will be assembled and tested using many different facilities, systems, and capabilities at KSC. The components will be stacked in the Vehicle Assembly Building (VAB) and transported to the launch pad via the mobile launcher and crawler transporter. After launch, the reusable components will be recovered and the process will start again.

The facilities that were designed for the Apollo and Space Shuttle programs will be upgraded and modified for the Constellation Program. Some modifications will be extensive. The Orion spacecraft will be assembled and tested in the Multi-Purpose Processing Facility and the Operations and Checkout Building. The solid rocket boosters (SRBs) will be processed in the Assembly Refurbishment Facility and the SRB Rotation, Processing, and Surge Facility. After extensive modifications, the same VAB that has served the Apollo and Space Shuttle programs will continue its duties for the Constellation Program. In the VAB, SRB segments, the upper-stage booster, and Orion service and command modules will be lifted by cranes and stacked on a new mobile launcher. All systems will be checked here before rollout to the pad.

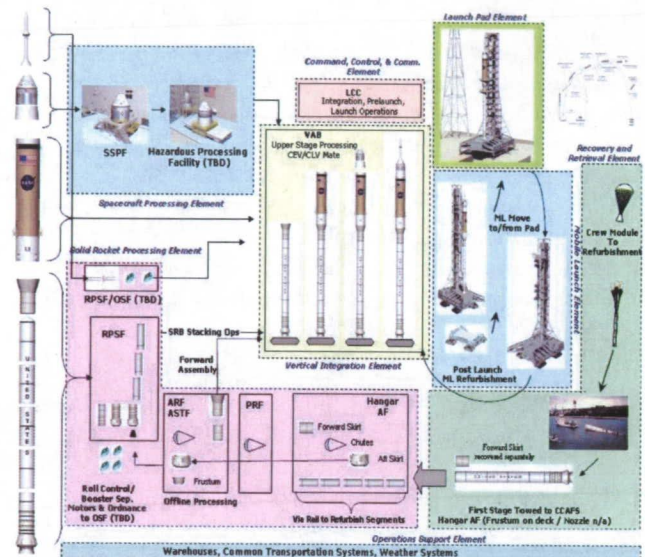


Figure 2. Vehicle Processing Flow

A "clean launch pad" concept is being used for the Constellation system. Many of the systems that reside on the pad will be moved inside the new mobile launcher. This will reduce maintenance on systems exposed to the environment and duplication of hardware at the VAB. The systems travel with the vehicle. Because the Ares I integrated stack (the Orion spacecraft sitting atop the Ares I launch vehicle) will be significantly taller than the Space Shuttle, a new 594-foot-tall lightning protection system has been erected. Also because of the vehicle height and to accommodate a new mobile launcher and modified launch pad, a new emergency egress system is being developed. A 300-foot-tall roller-coaster-like system will carry the astronauts to safety in case of emergency. The cryogenic fuel systems (liquid hydrogen and liquid oxygen), sound suppression water system, gaseous nitrogen and oxygen systems, and environmental control systems from the Space Shuttle Program will be modified for the Constellation Program. Launch Pads 39A and 39B will be modified for the new launch vehicles. Pad 39B is being modified first.



Figure 3. Ares I at Launch Pad B



Figure 4. New Mobile Launcher under Construction at KSC

Constructing a completely new mobile launcher is the biggest effort at KSC. It will definitely be another modern marvel. Most of the systems necessary to process and launch Ares I will be housed in the mobile launcher base and up and down the tower. Connections for power, fluids, and gases will be made at the base, and infrastructure for power, fluids, command, control, and communications will be installed along the tower. A number of umbilicals carrying fuel, fluids, gases, power, and data will be connected to the vehicle from the tower. The tower will contain three electrical rooms and a number of access platforms. The entire system will be carried from the VAB to the launch pad on the same crawler transporter that has served Apollo and Shuttle.

Over 70 systems at KSC are being modified or upgraded for the Constellation Program, touching every discipline of engineering, among them,

- gaseous systems for purges, environmental control, and breathing air;
- fluid systems for hydraulics, cryogenics, and sound suppression water;
- mechanical systems for umbilicals to supply commodities, power, and data, for arms and platforms to provide access, and for emergency egress;
- facility systems for power, buildings, structures, cranes, security, fire detection and suppression, lightning protection, plumbing, heating, ventilation, and air conditioning;
- electrical systems for power to Orion, Ares I, and ground support equipment, for detecting leaks of hazardous gases, for acquiring data from sensors that measures pressure, stress, temperature, vibration, and acoustics, and for monitoring range safety, radio frequencies, weather, and lightning; and
- communication systems for transmission, intercomms, radio, timing and countdown, and imagery (there are more than 70 cameras at the pad alone).

The new launch control system will operate from the same launch control center that served Apollo and Shuttle. This system commands, controls, and monitors all the vehicle subsystems and the ground support equipment (GSE) for testing, checkout, processing, and launch. The launch control system will be based on open software architecture, industry and agency standards, and the integration of mature commercial software and hardware technology. Main components of the system are control and advisory workstations, operations support servers, vehicle gateway, GSE gateway, and industrial programmable logic controllers, which will be the heart of the embedded system control and monitoring.



Figure 5. Launch Control Center

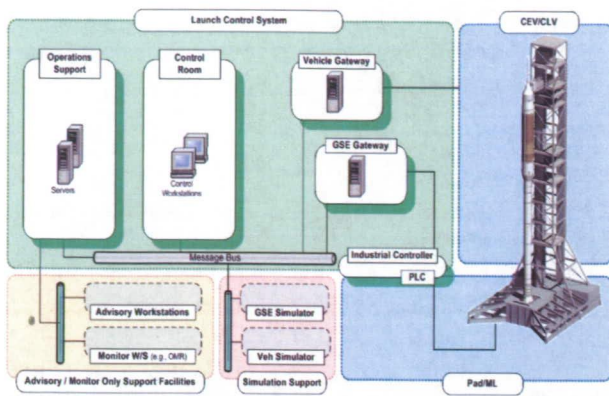


Figure 6. Launch Control System

4 Design, development, and test facilities

The KSC Engineering Development Laboratory and Launch Equipment Test Facility (LETF) are being used to design and test new subsystems.

The Engineering Development Laboratory houses the design and development labs for the Constellation electrical GSE subsystems, including the power lab, controls lab, sensors and transducers lab, sensor data acquisition lab, weather subsystem lab, hazardous-gas leak detection lab, electromagnetic-interference chamber, and electronics labs. The labs are used to develop proof-of-concept designs and prototypes and to test and integrate subsystems and components.

The LETF will serve as the testbed for many subsystems and components designed and developed by KSC for the Constellation Program. The test facility has many test capabilities, such as a 600-ton test fixture, water flow test loop, vehicle motion simulator (VMS), cryogenic system, and data acquisition system.

The 600-ton test fixture is a multipurpose proof-loading apparatus. A variety of articles can be tested for tension or compression in either the vertical or horizontal direction. The versatility of the test fixture makes it possible to test a wide variety of large-scale GSE components that require periodic proof loading to remain in service. It can also test objects to failure so we can better understand their performance. Vertically, the fixture can test hardware up to 23 feet tall, 20 feet 9 inches wide, and 600 tons for tension and compression. Horizontally, it can test hardware up to 66 feet long, 20 feet 9 inches wide, and 400 tons for tension and compression. Typical GSE that is tested include slings and lifting beams.



Figure 7. 600-Ton Test Fixture

The water flow test loop is used to verify performance of various fluid components, including valves, pumps, and flow meters. The system is a set of closed, independently operated, concentric flow loops that are supplied from a pair of stainless-steel tanks. Each loop consists of a large main line and a smaller bypass line. The loops are supplied through a common feed line and return through a common return line. Flow is induced by means of variable-frequency-driven pumps. The test loop has the following capabilities and specifications: tank capacity: 5,200 gal each (total 10,400); maximum tank pressure: 125 psig; maximum ullage pressure: 110 psig; large-pump maximum flow rate: 1,700 gpm; small-pump maximum flow rate: 400 gpm; large-pump maximum discharge pressure: 300 psig; small-pump maximum discharge pressure: 130 psig; large-pump maximum revolutions per minute: 3,450; small-pump maximum revolutions per minute: 3,350.

The VMS will simulate all of the motions that a launch vehicle will experience from the time it is rolled out of the VAB, through roughly the first half second of launch. The purpose of the VMS is to enable the development and qualification testing of umbilical systems in both prelaunch and launch environments and of launch vehicle access arms in a prelaunch environment. The primary role of the cryogenic system is to provide support for GSE and umbilical development and qualification testing. The cryogenic system consists of onsite storage of liquid nitrogen, connections for tanker delivery of liquid hydrogen, piping, valves, and control devices. With test fixtures at the LETF, GSE and umbilical systems and components will be subjected to pressures and cryogenic temperatures (not flow rates) that simulate launch processing conditions. For liquid-oxygen systems, the LETF cryogenic system will use liquid nitrogen as test media, with permanent onsite storage and recirculation for long-duration testing (greater than 24 hours). For liquid-

hydrogen systems, the LETF cryogenic system will use once-through liquid hydrogen with portable storage (over-the-road tankers) for the duration of the tests only. Pressure requirements will be accommodated by the use of gaseous nitrogen, gaseous helium, and the pressure-building capability provided by the cryogens themselves. The control room data acquisition system will condition, acquire, and archive transducer signals (i.e., temperature, pressure, strain, displacement, vibration) from test articles and LETF test fixtures during testing of components and subsystems.

5 Ares I-X flight test

NASA's first flight test of the Ares I crew launch vehicle, called Ares I-X, is being launched in 2009. The Ares I-X flight will provide an early opportunity to test and prove some of the hardware, facilities, and ground operations associated with Ares I. The flight test will also provide critical data during ascent of the integrated stack. Data collected will help verify the effectiveness of the rocket's design and ensure that it is safe and stable in flight before astronauts begin traveling into orbit. KSC will develop the ground control system and process the vehicle and spacecraft segments. The Ares I-X flight test will be launched from a Shuttle mobile launcher platform with minimal modifications.

The Ares I-X test vehicle will be similar in mass and size to the actual Orion and Ares I vehicle systems, but it will incorporate a mix of proven spaceflight and simulated, or mockup, hardware. The test vehicle will be powered by a single, four-segment reusable solid rocket booster—flight hardware currently in the Space Shuttle inventory—modified to include a fifth inactive segment to simulate the Ares I five-segment booster. Mockups of the upper stage and the Orion crew module and launch abort system will be used to simulate the integrated spacecraft. The flight test profile will closely approximate the flight conditions the Orion/Ares I vehicle is expected to experience through Mach 4.7—more than four times the speed of sound. Approximately two minutes into flight, at about 130,000 feet, the launch vehicle's first stage will separate from the upper stage. The maximum altitude, or apogee, of the flight test will be about 150,000 feet.

KSC will use existing facilities for assembly, testing, and launch of Ares I-X. The first-stage motor segments arrived by rail car and will be prepared for assembly on top of a mobile launch platform in the VAB. The upper-stage simulator was shipped by barge and the Orion simulator was sent by air. These components will be assembled into super segments and integrated onto the first stage, and the completed Ares I-X vehicle will roll out to Launch Complex 39B. From the Launch Control Center, the launch team will perform final checkout and launch the Ares I-X rocket. During the Ares I-X flight test, the vehicle upper-stage simulator and the Orion crew module and

launch abort system mockup will separate from the first stage and fall into the Atlantic Ocean. The first-stage booster will continue through a complete recovery sequence, releasing its Ares I prototype three-stage parachute recovery system, falling safely into the ocean, and floating until the hardware can be retrieved for inspection and analysis. Data gathered from the first stage will provide vital information on hardware and software performance and also will be used to fine-tune ground operations.

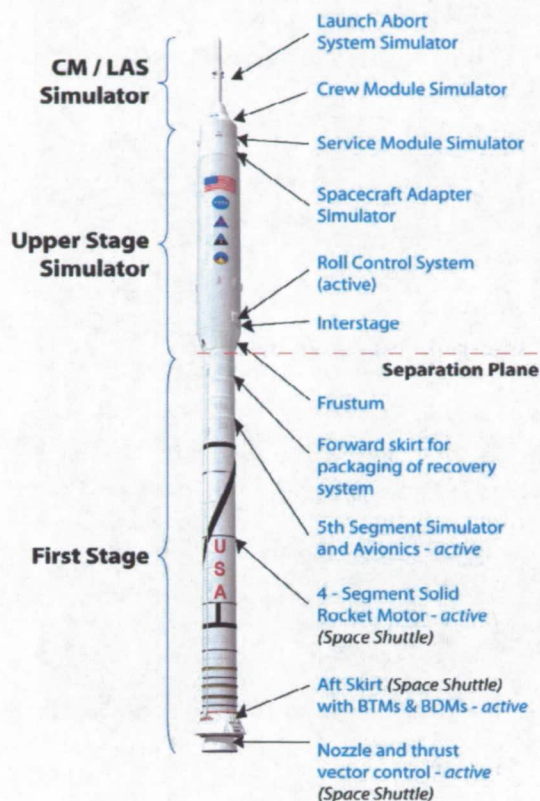


Figure 8. ARES I-X Test Vehicle

The primary test objectives for the Ares I-X flight are to demonstrate the flight control system performance during ascent and to gather information to help engineers better understand how to control the Ares I system's roll torque during flight. Roll torque is the force that causes the rocket to rotate, just like the torque exerted by a hand upon a jar lid causes the lid to turn. The rocket generates roll torques by the manner in which the propellant burns, as well as the vehicle aerodynamics. The test will characterize the flight environment during stage separation to help us better understand any possible effects on the future Ares upper-stage J-2X engine. It also will test the first-stage parachute recovery system and validate assembly and processing activities, as well as launch and recovery operations. Several secondary test objectives are also planned for the flight test. NASA engineers will analyze data to learn how effective the first-stage separation motors perform and to better understand the flight environments the vehicle must withstand during its ascent. The flight test

also will demonstrate flight procedures and operations, establish potential access locations in facilities and on the launch pad, and assess induced loads that are caused during the operation of the vehicle system on the launch pad.



Figure 9. Ares I-X Being Stacked in the VAB

6 Conclusions

It is an exciting time to be at NASA. The new age of space exploration that will take us back to the Moon, to Mars, and beyond presents great engineering challenges. Along this grand journey, new discoveries and innovations will be made, many of them at Kennedy Space Center. It's a great time to be an engineer, a NASA engineer, and especially a Kennedy Space Center engineer. Our only limitation is our imagination.